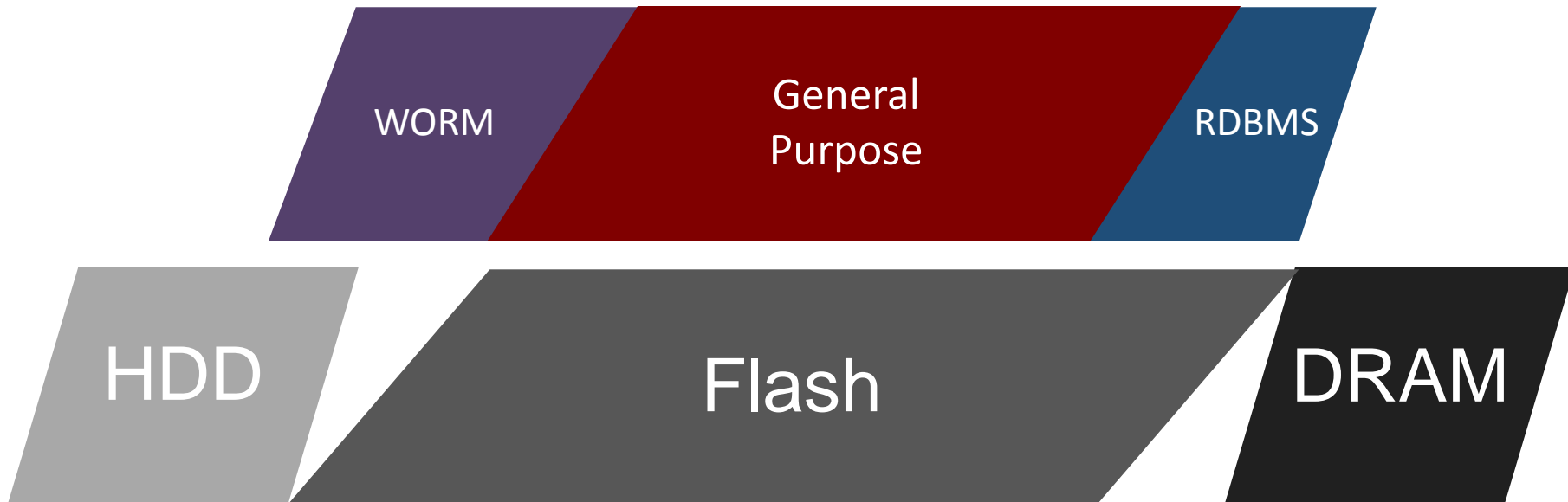


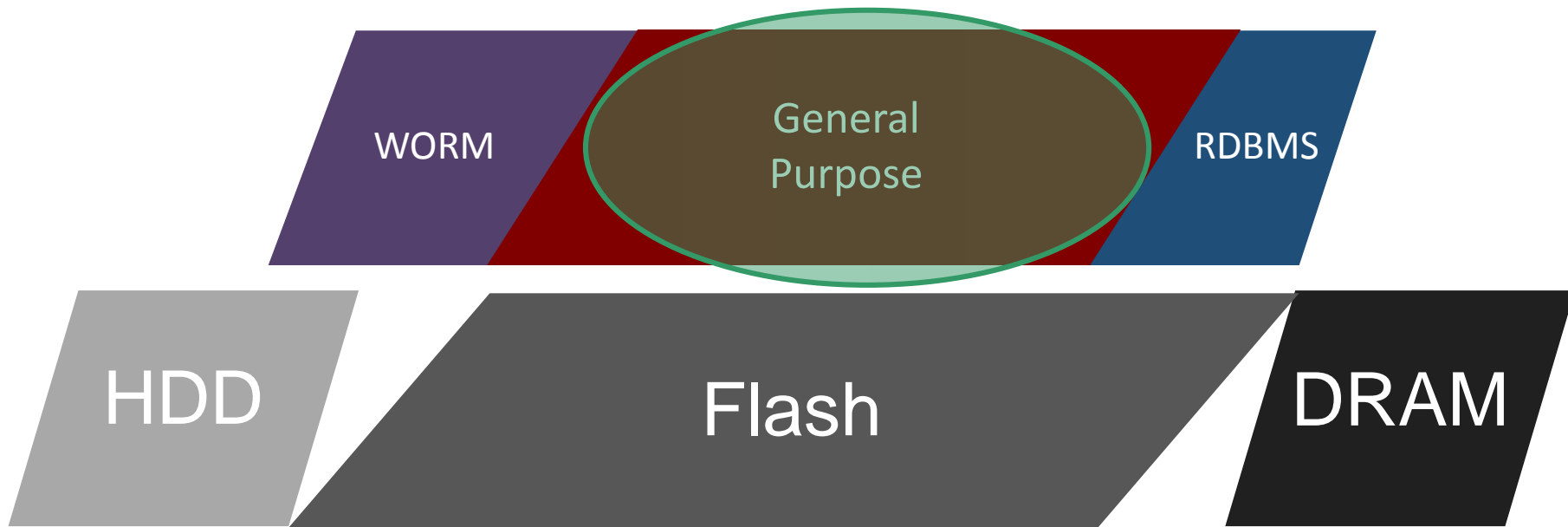
Replacing the FTL with Cooperative Flash Management

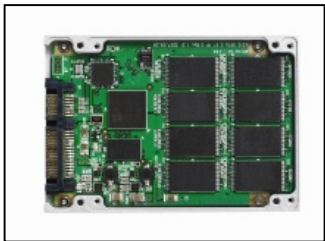
Mike Jadon
Radian Memory Systems
www.radianmemory.com

Data Center Primary Storage



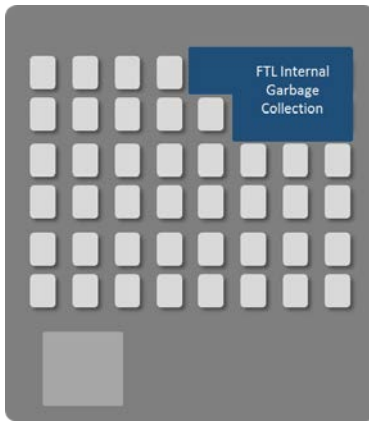
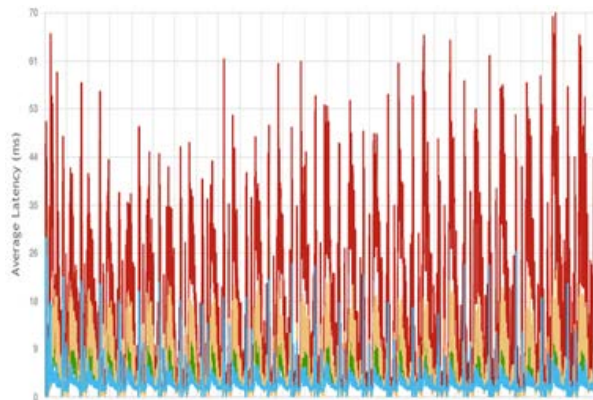
Data Center Primary Storage





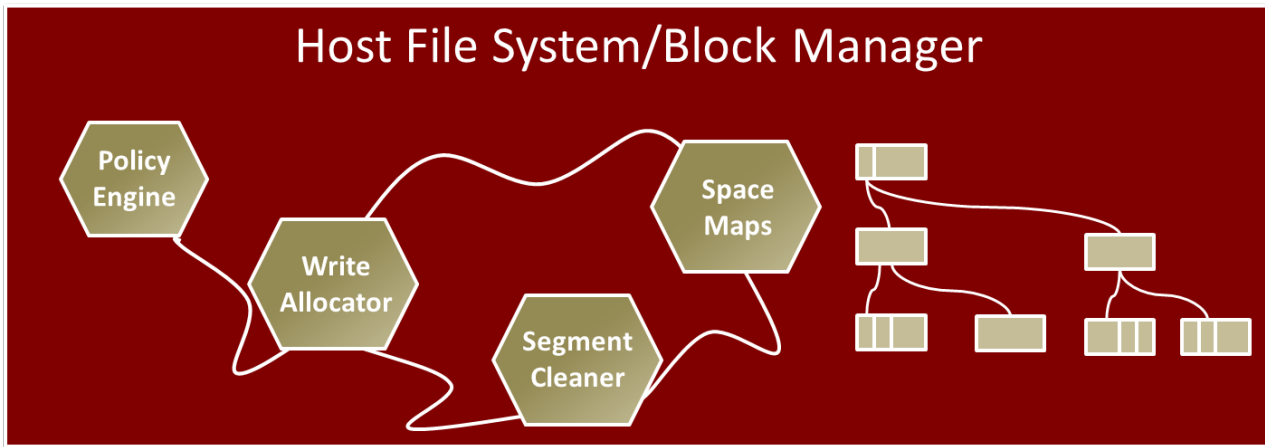
Flash SSD

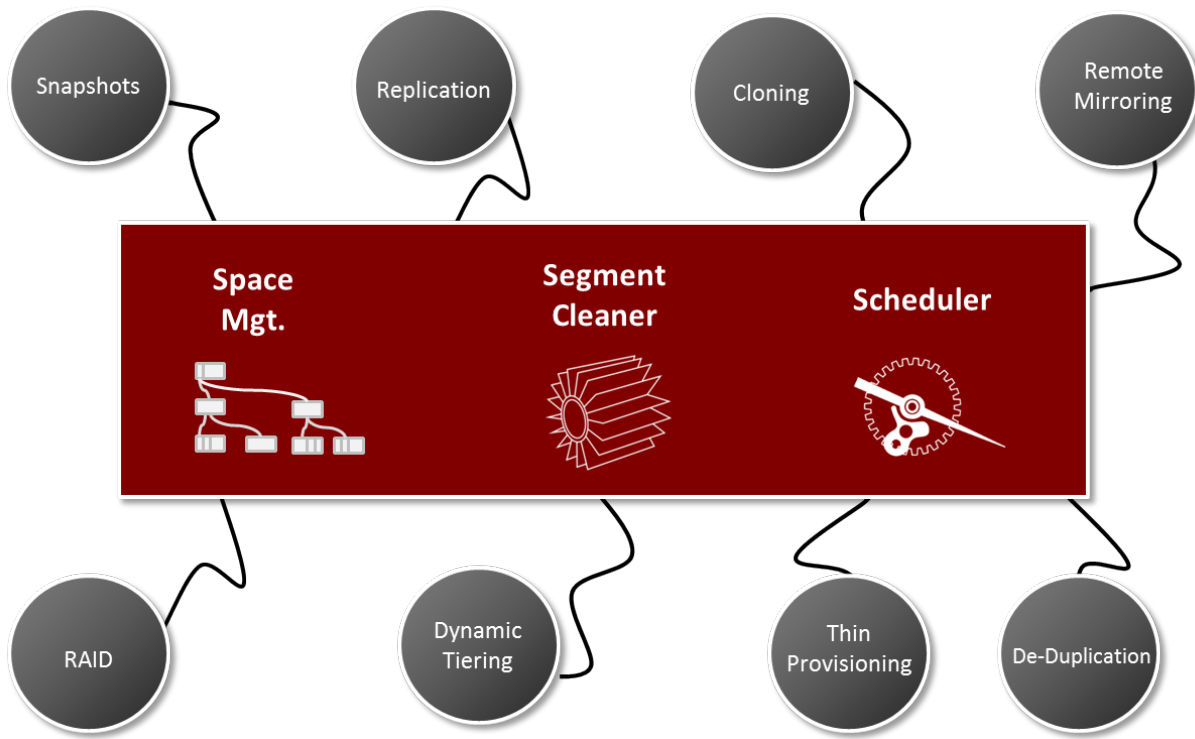
- Unpredictable Latency Spikes (QoS)
- Cost
- Endurance (Wear Out/TCO)

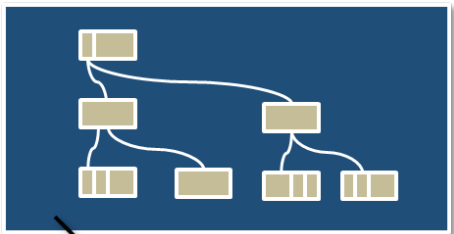


Advanced Systems

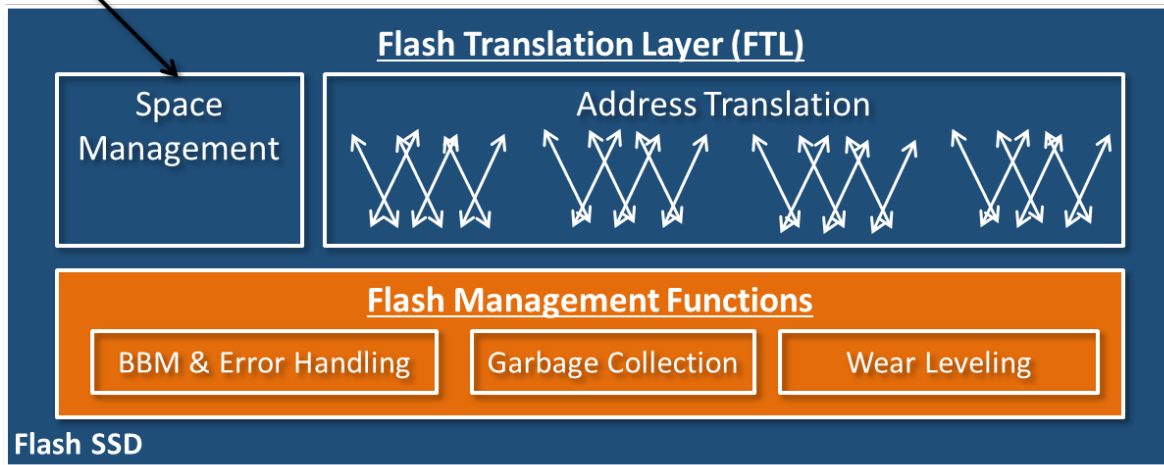
- Purpose-Built storage systems
- All-Flash Arrays
- Hybrid SSD/HDD
- Advanced local file systems
- Software-Defined Storage architectures
- Hyperconverged systems
- Object/Key Value Stores
- Certain In-Memory Data Base applications

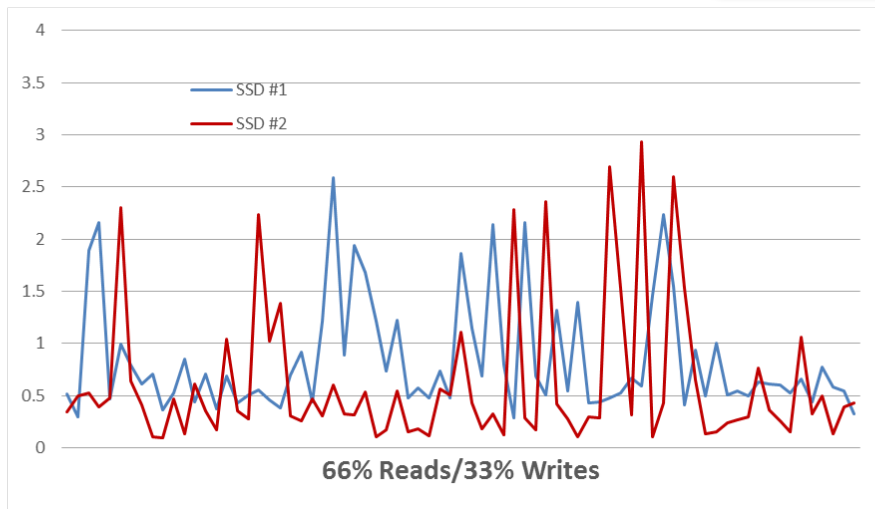
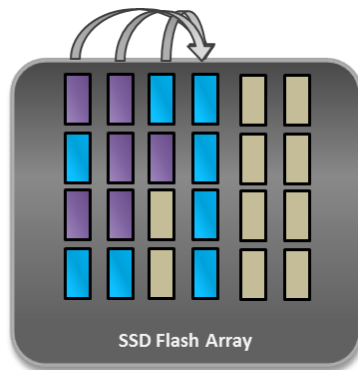
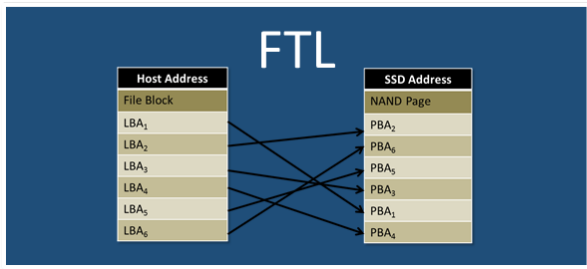






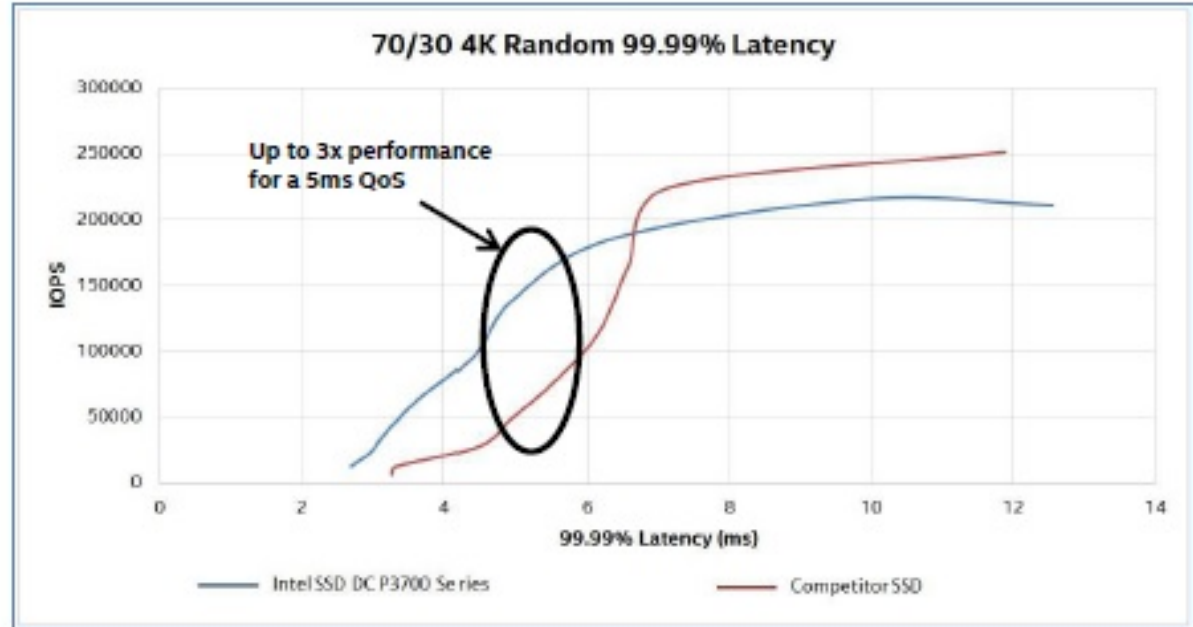
- Backwards Compatible
- Simple Contract

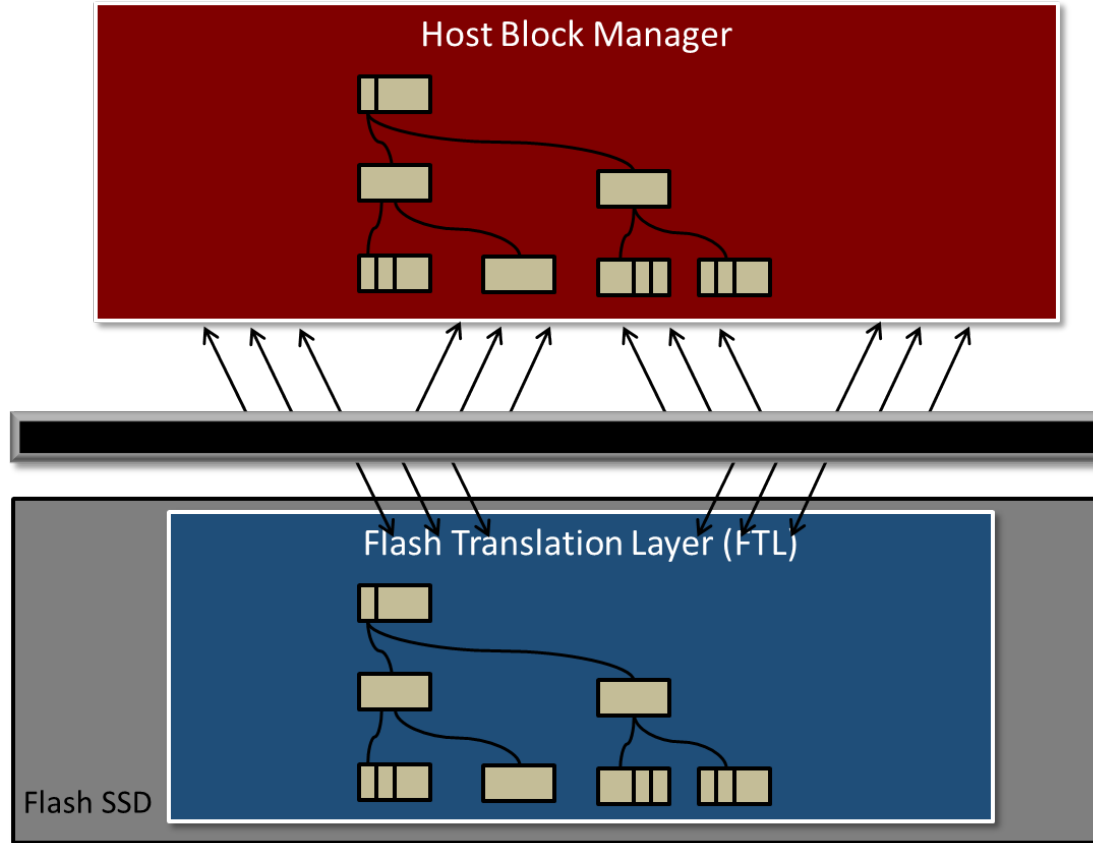


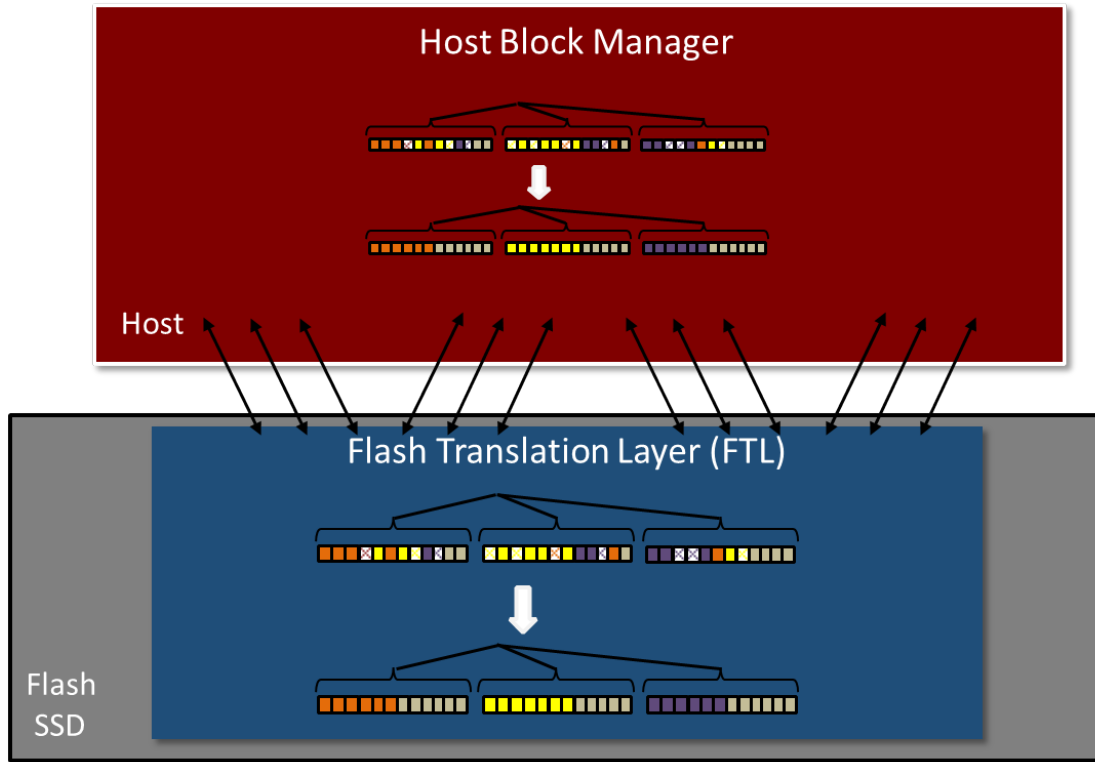


Latency
@
IOPS

Figure 3: Relationship between 99.99% QoS and Performance (Source: Intel)







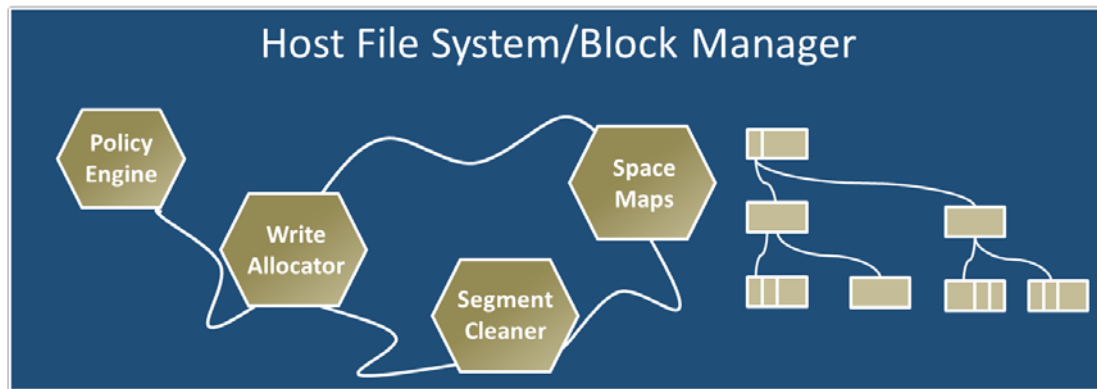
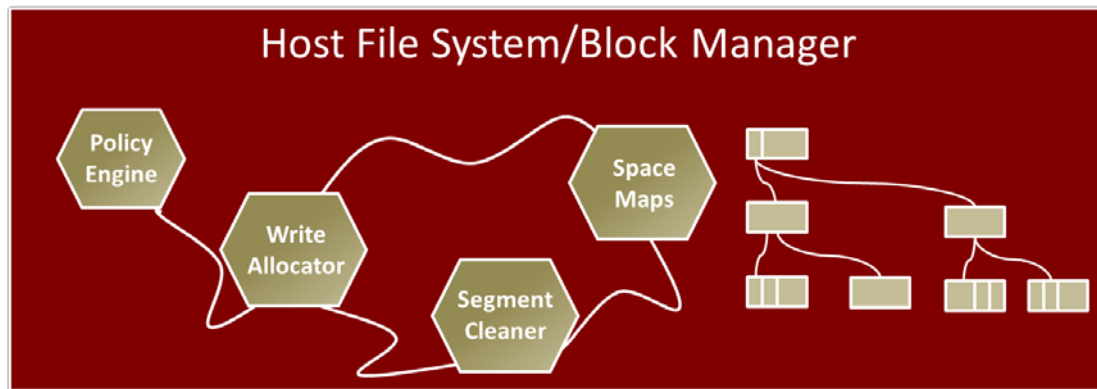
Standardizing Storage Intelligence for SSDs

- TRIM
- Hinting and Optimal Stripe Size

FTL SSD Intelligence

- Multi-Stream Writes
- Intelligent placement of data on the storage device
- Intelligent management of garbage collection and overprovisioning

Challenges with FTL Storage Intelligence



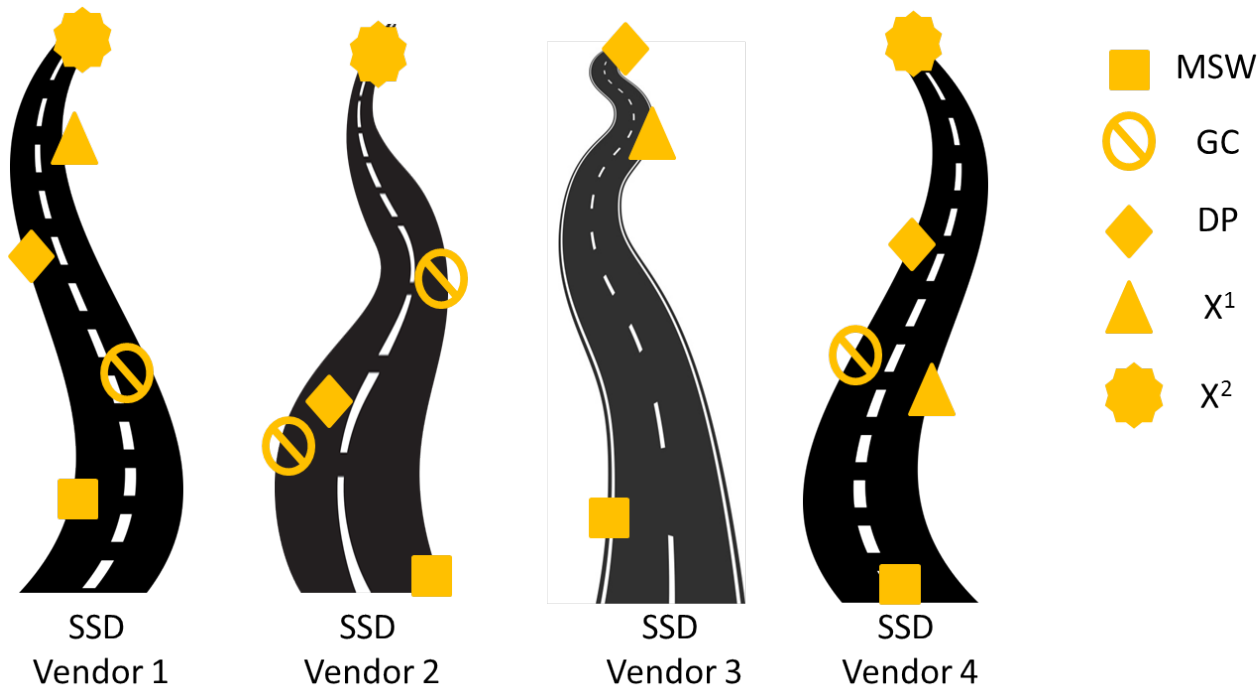
Challenges with FTL Storage Intelligence

Universal API

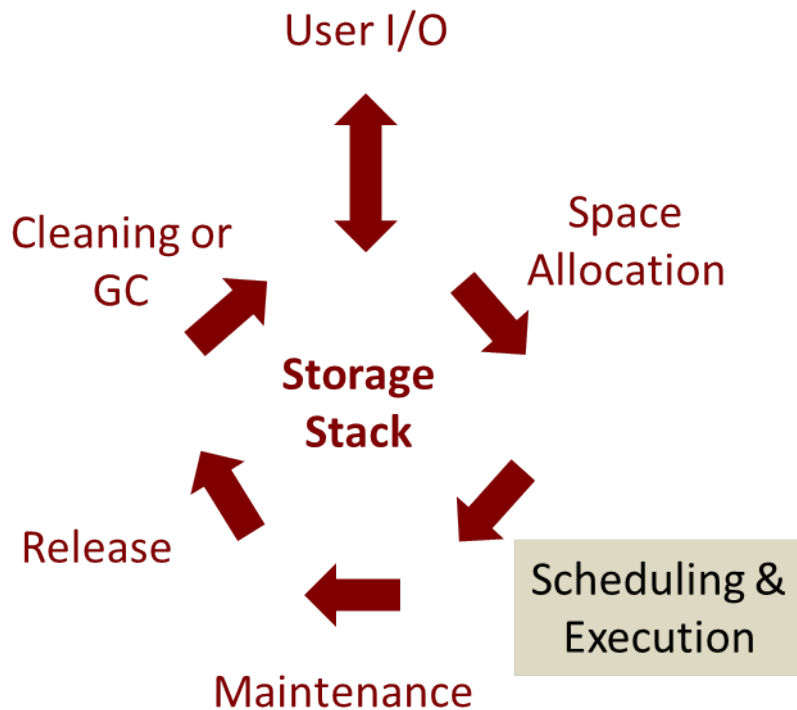


- Huge number of potential parameters
- Information on caching, prioritization, garbage collection, scrubbing, hot/cold
- Information has to be continuously prepared and communicated on every op
- Set up overhead on system software and through communication chain
- Complex Host/Device Contract

- When and what function will be offered by each vendor?
- Will need to continuously add options
- Each vendor's implementation will produce different results, interoperability, and dependencies

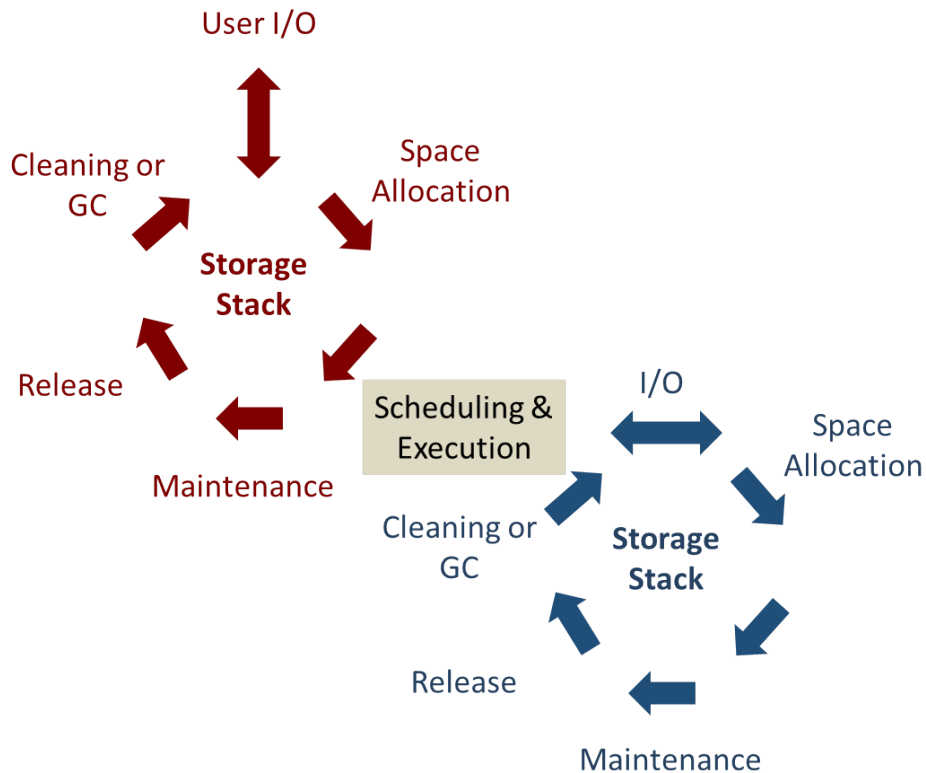


Data Lifecycle in Storage Software



- Management is required across the life cycle of data
- Process alignment

Data Lifecycle in Storage Software



- FTLs duplicate these processes
- High probability for disconnects
- Performance and latency impacted with every disconnect

Space
Mgt.



Segment
Cleaner



Scheduler



Space
Mgt.



Segment
Cleaner



Scheduler



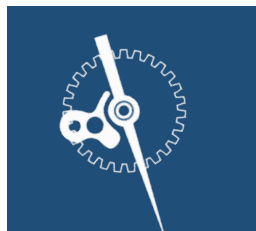
Space
Mgt.



Segment
Cleaner

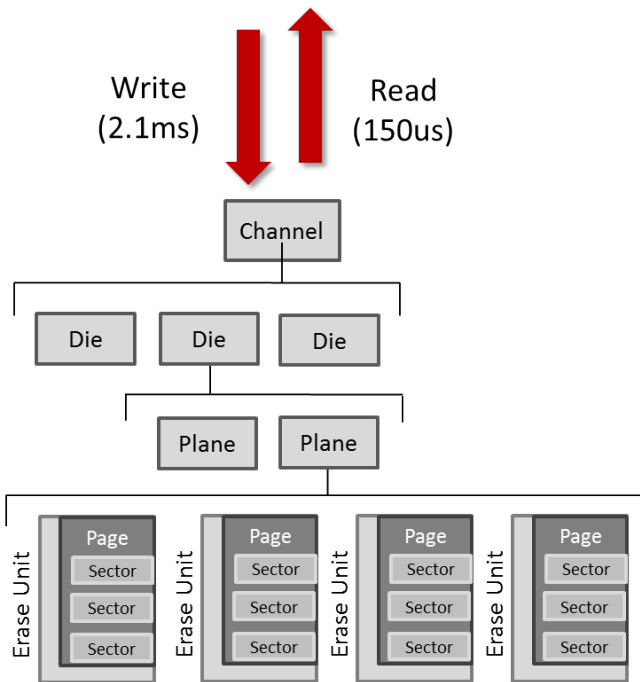


Scheduler



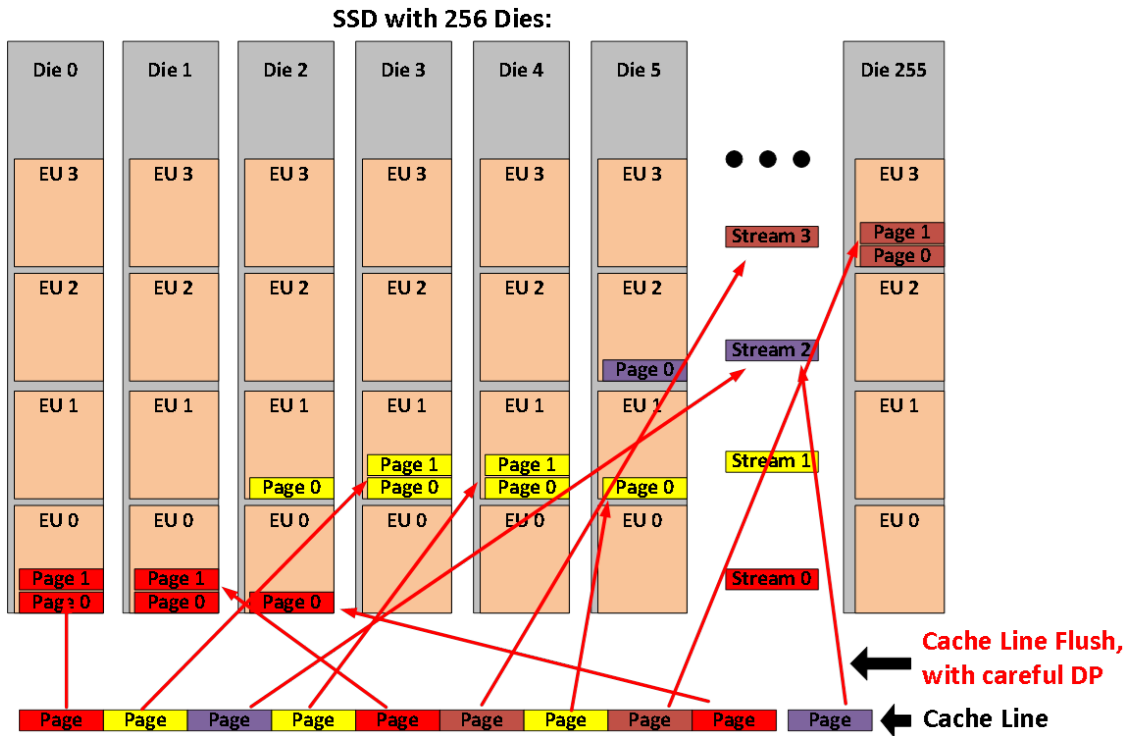
SSD Storage Intelligence and Latency Spikes

Read collisions



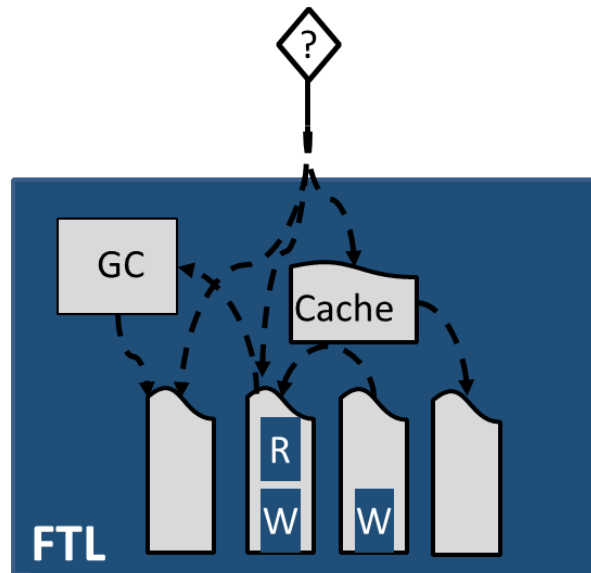
*“Your Read latency
is
your Write latency!”*

SSD Storage Intelligence and Latency Spikes

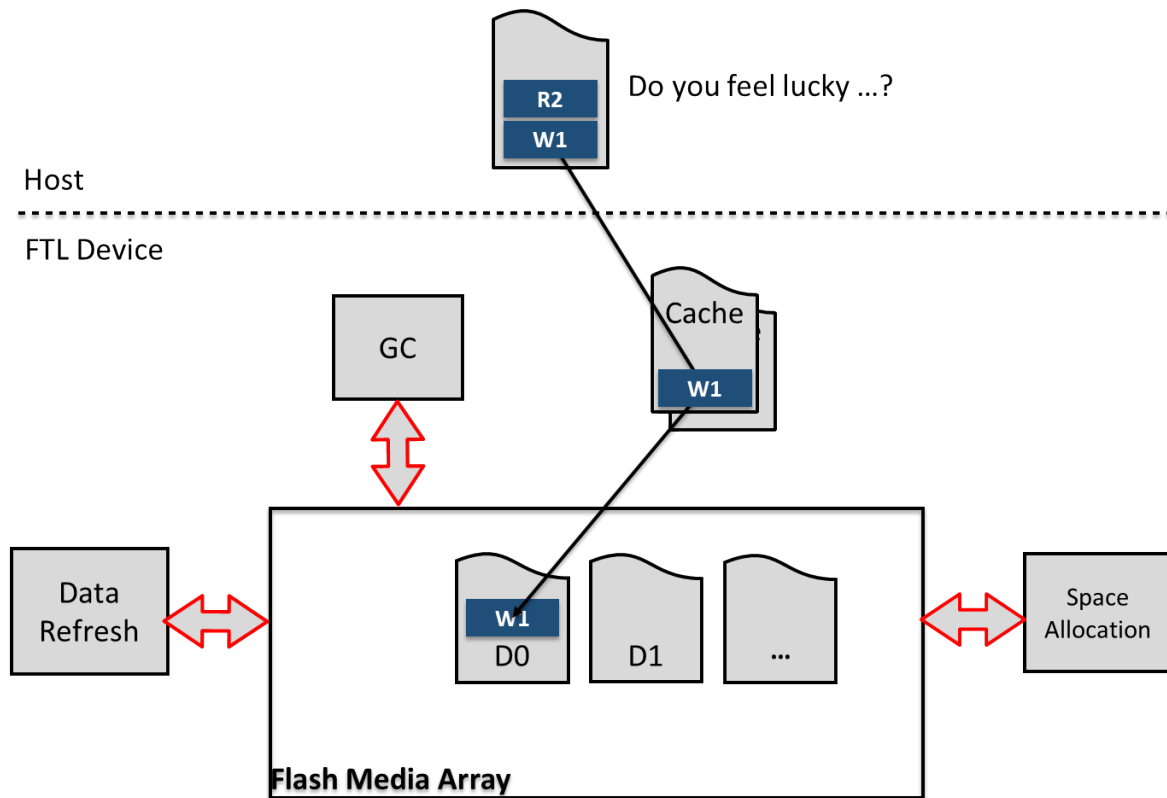


Lifecycle Scheduling and Execution

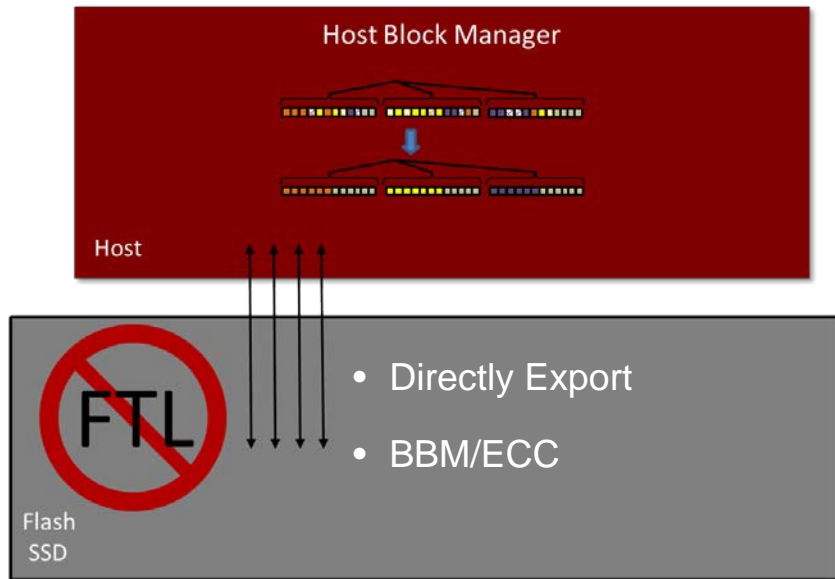
- Proprietary I/O pipeline
- Internal system with async processes: cache flush, garbage collection, data refresh, etc.
- Complex controls to mitigate



Lifecycle Scheduling and Execution



Software-Defined Flash



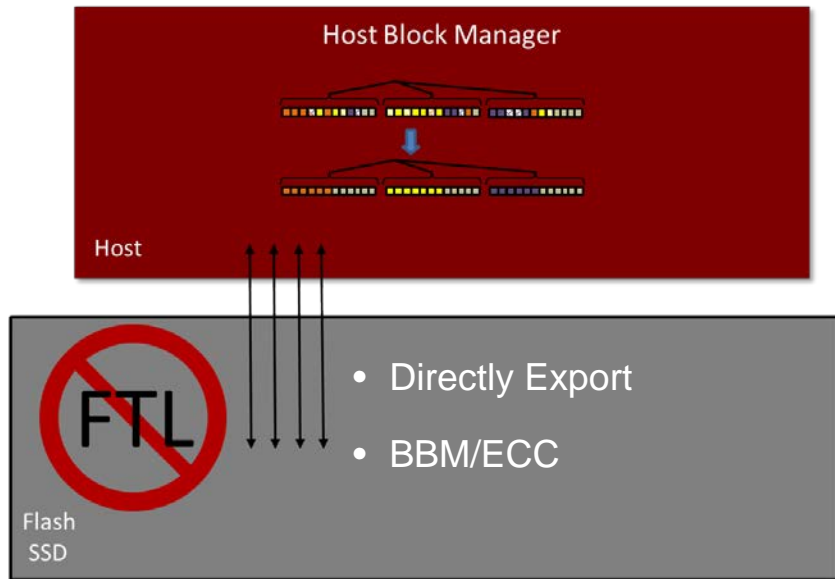
Software-Defined Flash:

- No FTL
- Direct Geometry Export
- Host stack performs all Flash Management processes

Results:

- Enables maximum parallelization
- Dramatic performance improvements

Software-Defined Flash



Challenges:

- Integration
- Burdens system with NAND attributes and constraints
- Does not provide Forward Compatibility
- Poor RAS capabilities
- Poor Scalability

Flash is now the most important
Storage System media

But every Flash SSD's
software is designed to
emulate a
Hard Disk Drive



Flash SSD

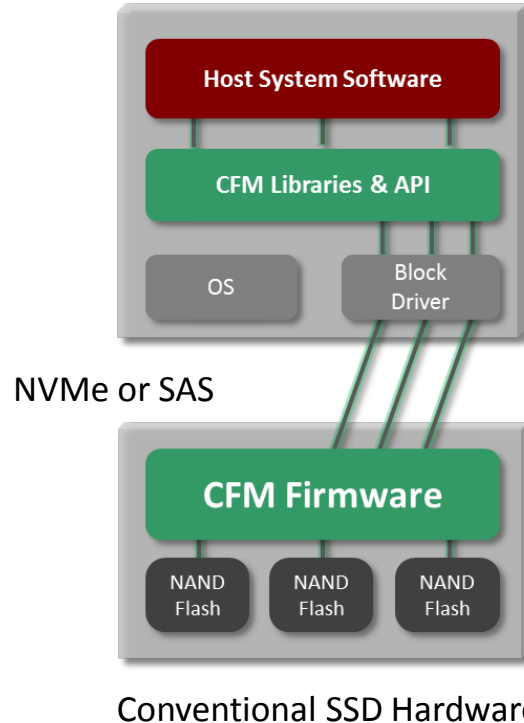


**Hard Disk
Drive**

Flash is now the most important Storage System media

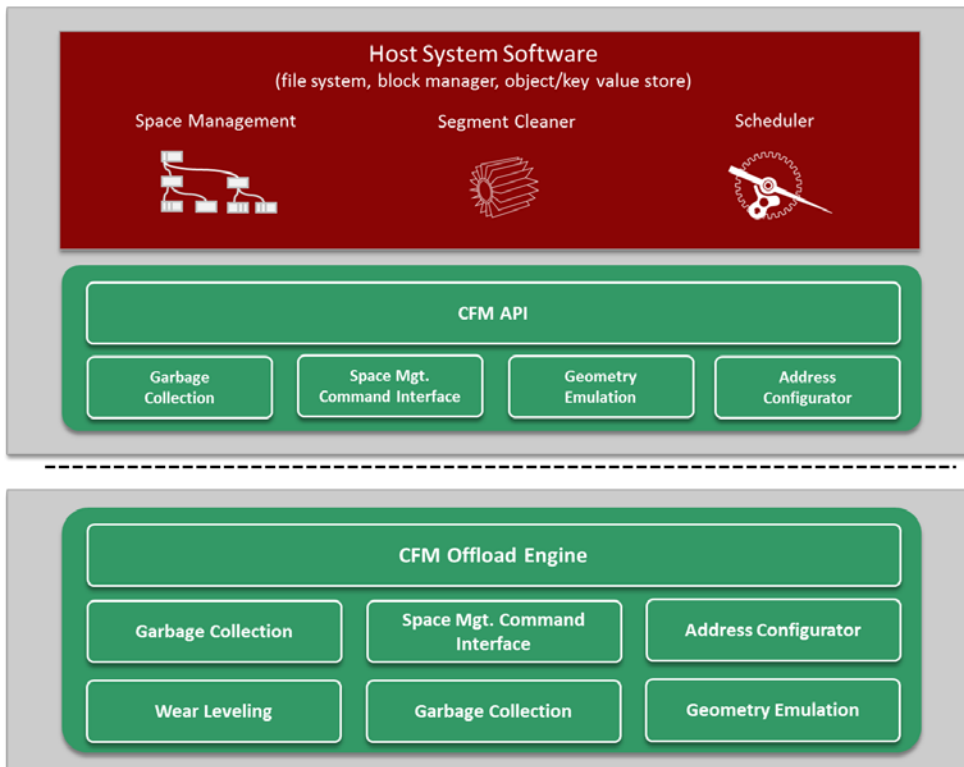


Flash SSD

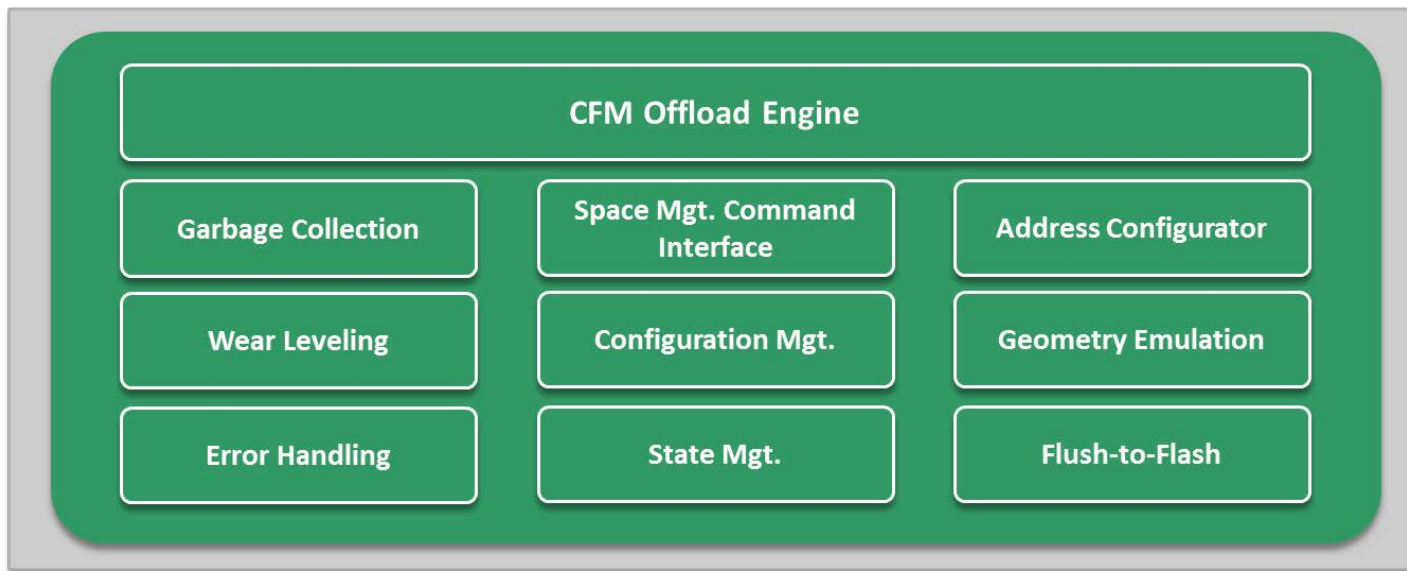


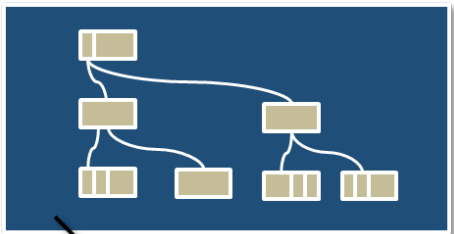
**Cooperative
Flash
Management**

System-Driven Architecture

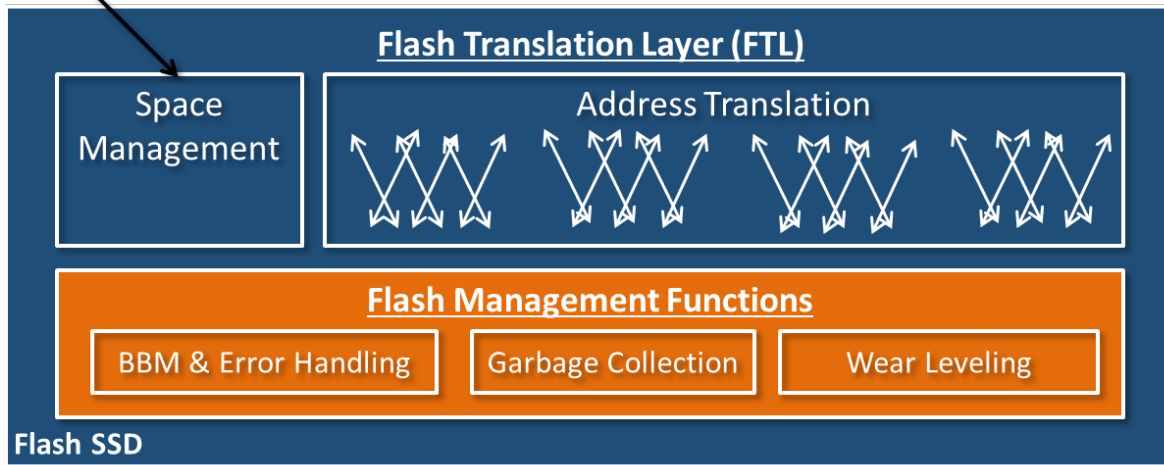


Offload Engine

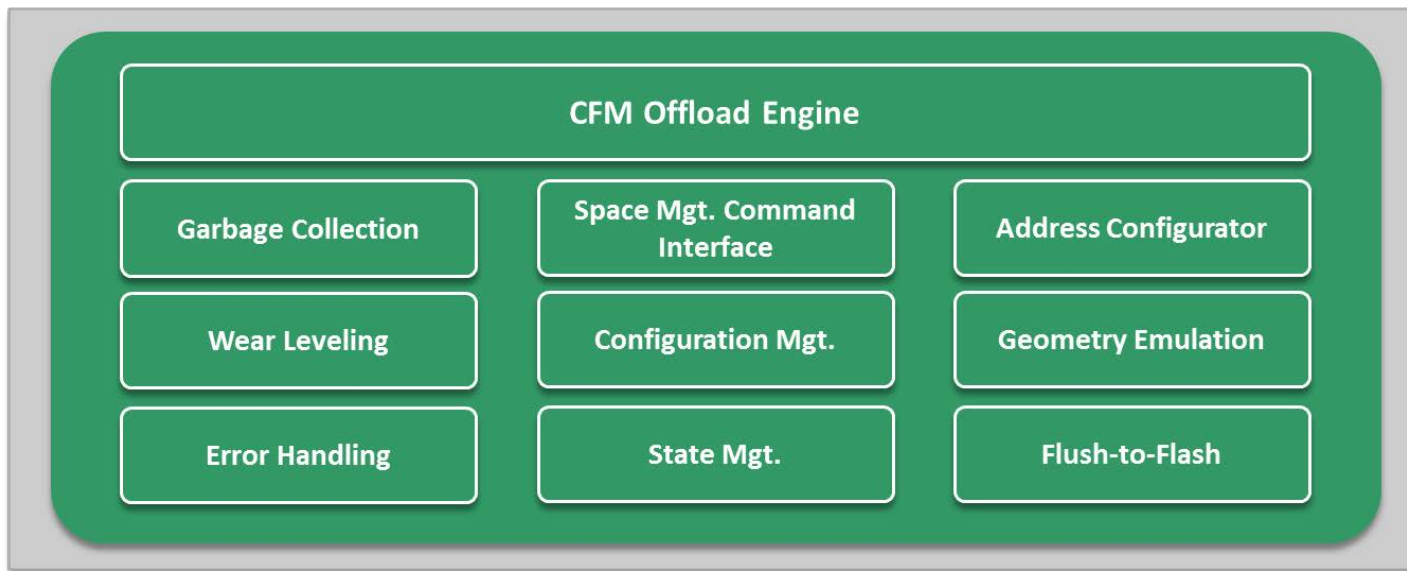




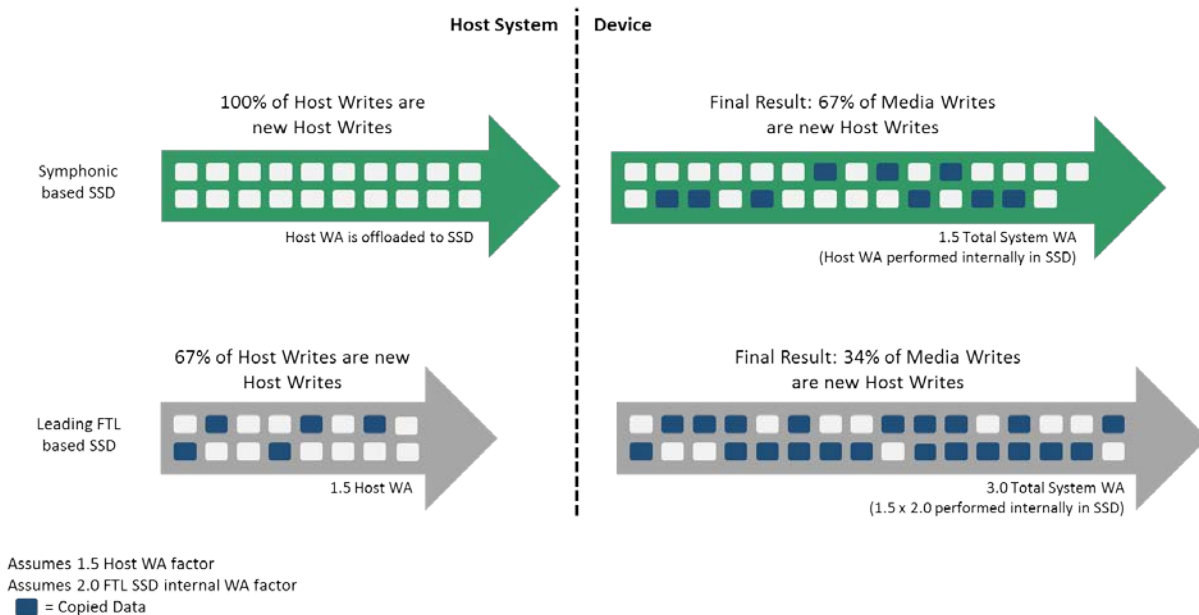
- Backwards Compatible
- Simple Contract



Offload Engine

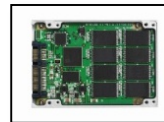
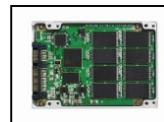
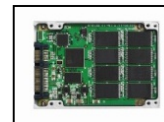
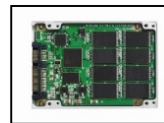
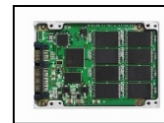
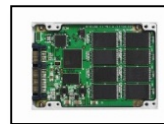
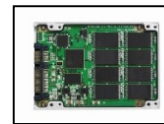
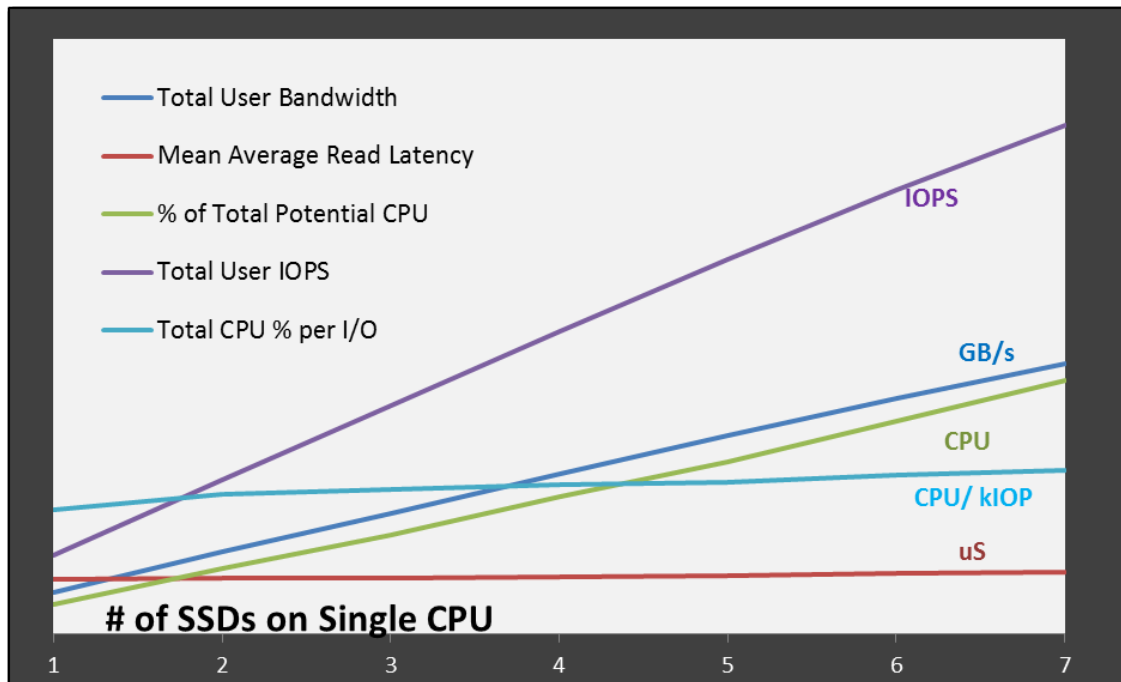


Offload Engine

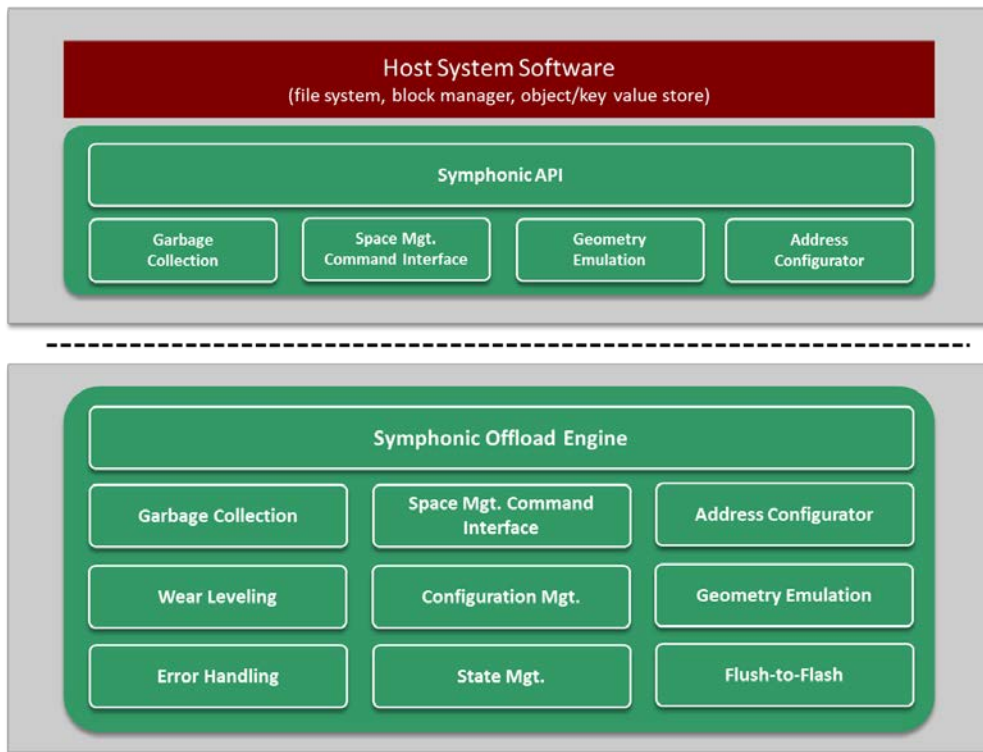


75% improvement in System-Level Write Amplification

Scalability

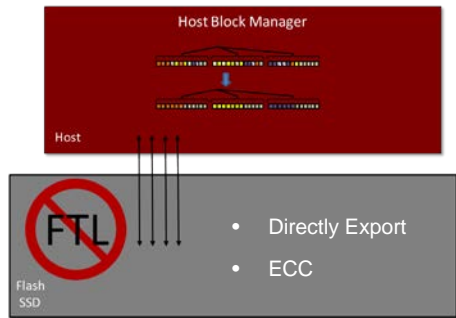


Abstraction



- Geometry Emulation
- Address Configurator
 - Enables Forward Compatibility
 - Reliability and FRU capabilities
 - Vendor Supported Warranties

Solving Software-Defined Flash for the Data Center



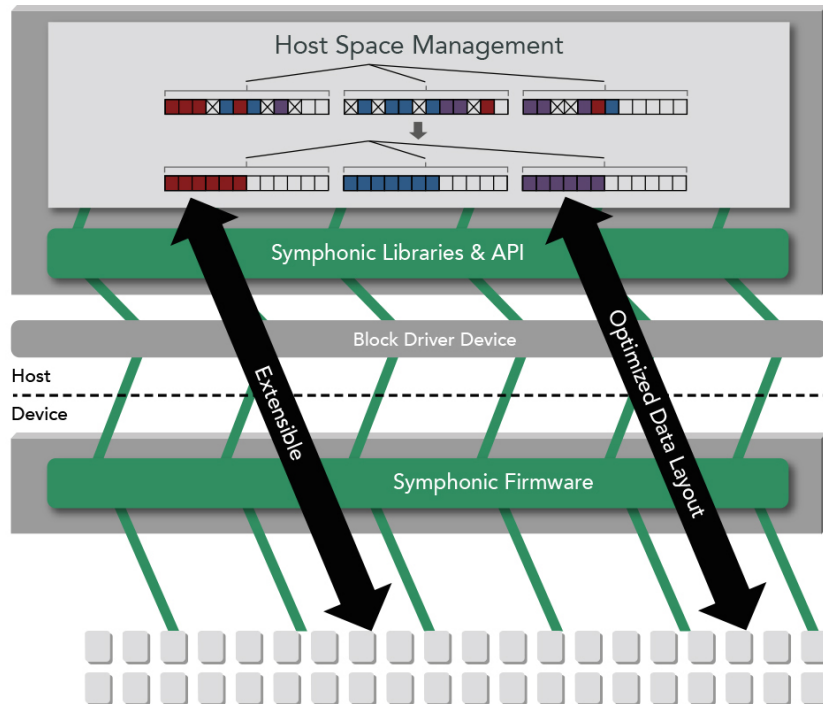
SDF Challenges:

- Integration
- Burdens system
- Forward Compatibility
- RAS
- Scalability

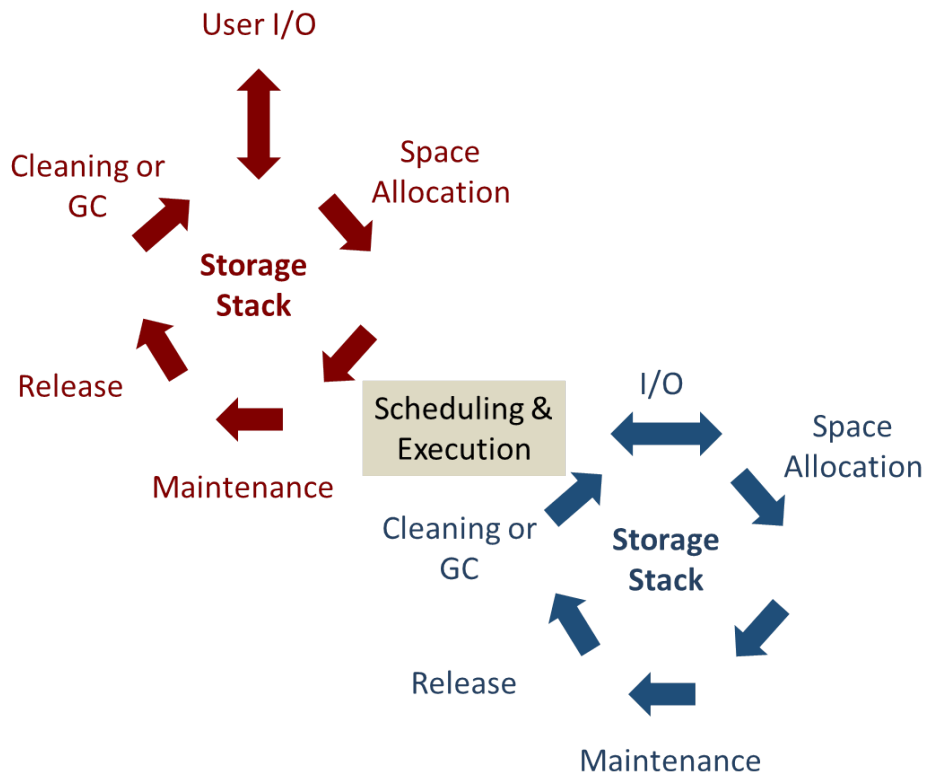
CFM:

- Geometry Emulation & Address Configurator
- Offload Engine
- Wear Leveling

Extensibility & Parallelization

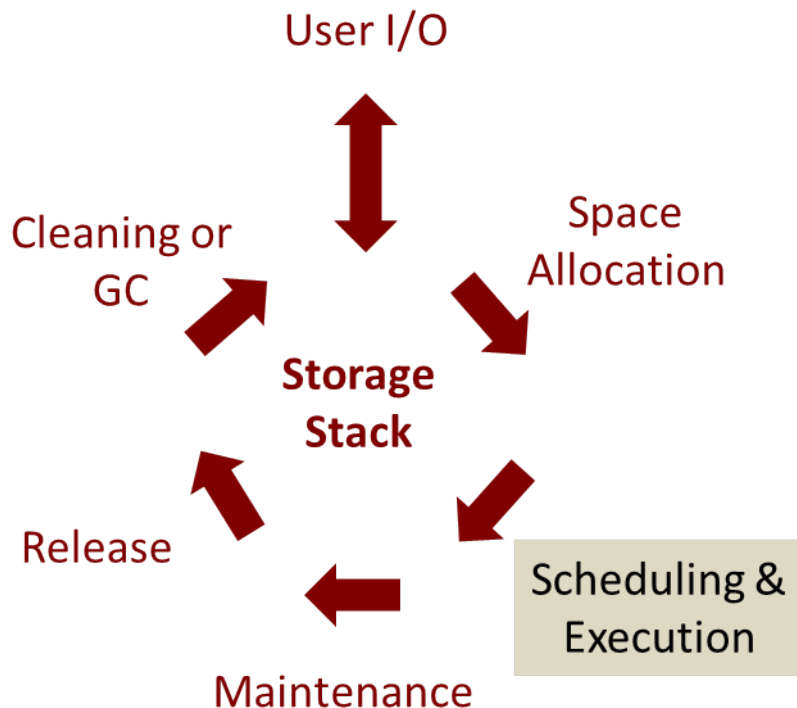


Data Lifecycle in Storage Software



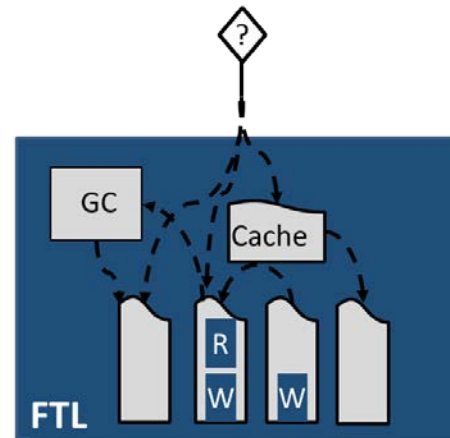
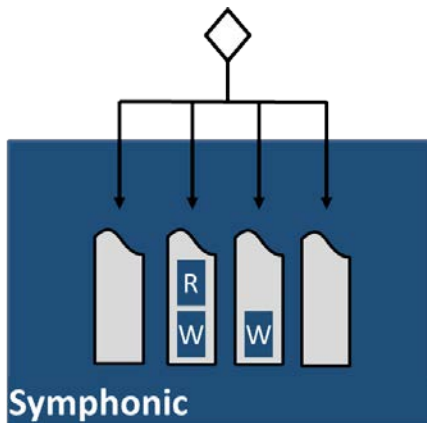
- FTLs duplicate these processes
- High probability for disconnects
- Performance and latency impacted with every disconnect

Data Lifecycle in Storage Software

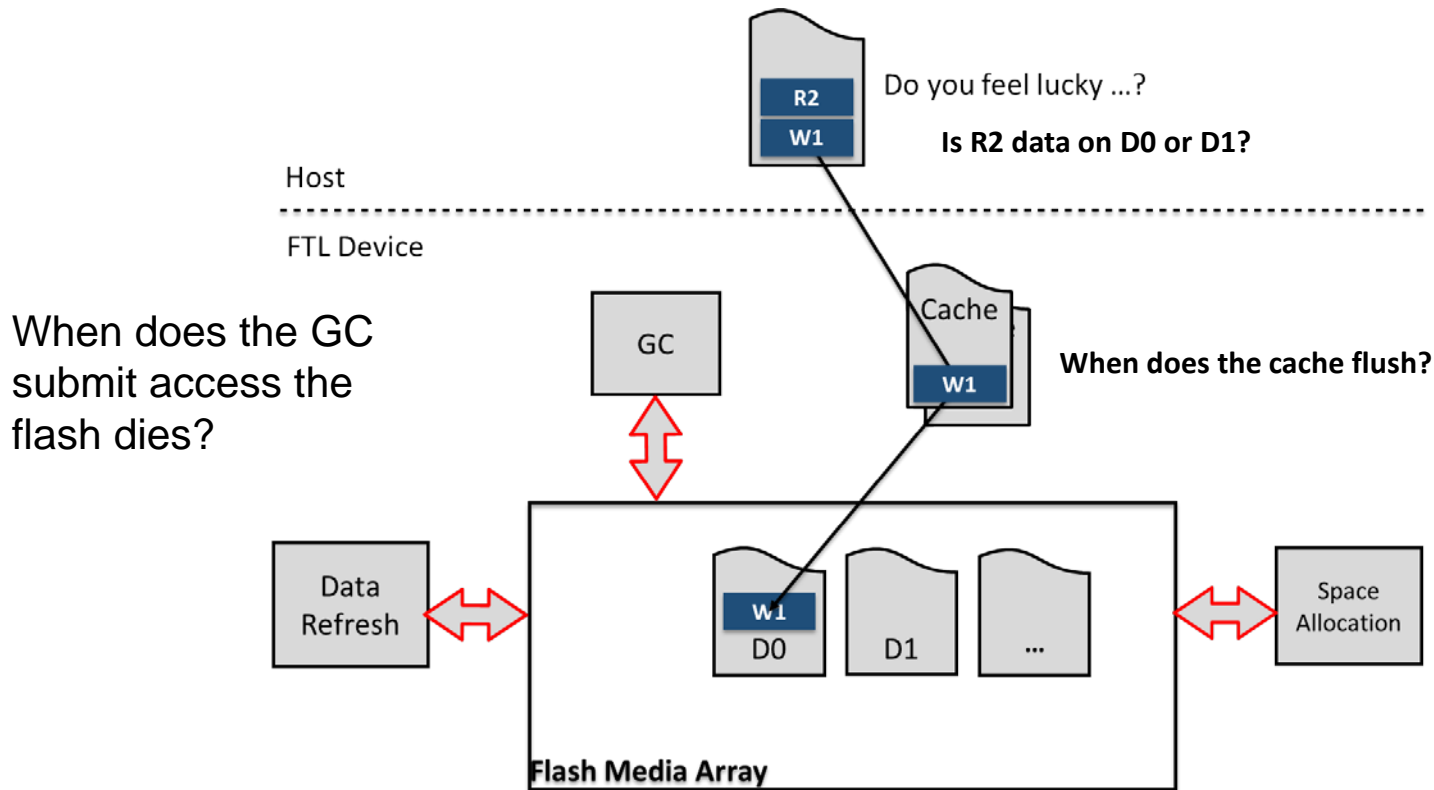


- CFM enables host ownership of the complete lifecycle in a combined system
- Implicitly supports different storage stacks with unique implementations and requirements

- CFM enables host optimization of flash resources
 - High Visibility into I/O queuing
 - High Parallelization
 - Predictable operation
 - Low-Latency & Low-Jitter
- I/O pipeline proprietary
- Internal storage system
- Internal Async processes (cache flush, gc, data refresh, etc)
- Complex controls to mitigate

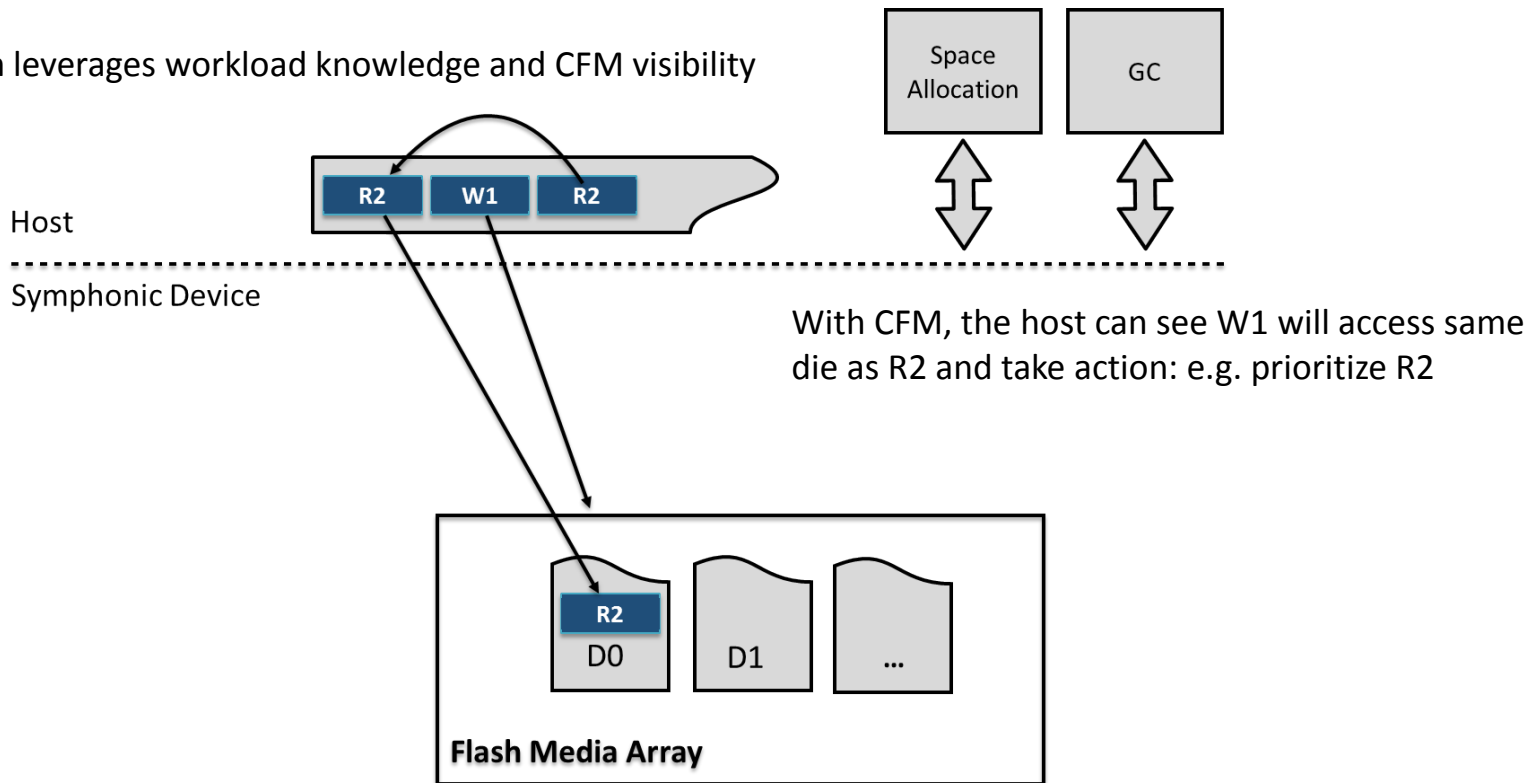


Lifecycle: Scheduling and Execution



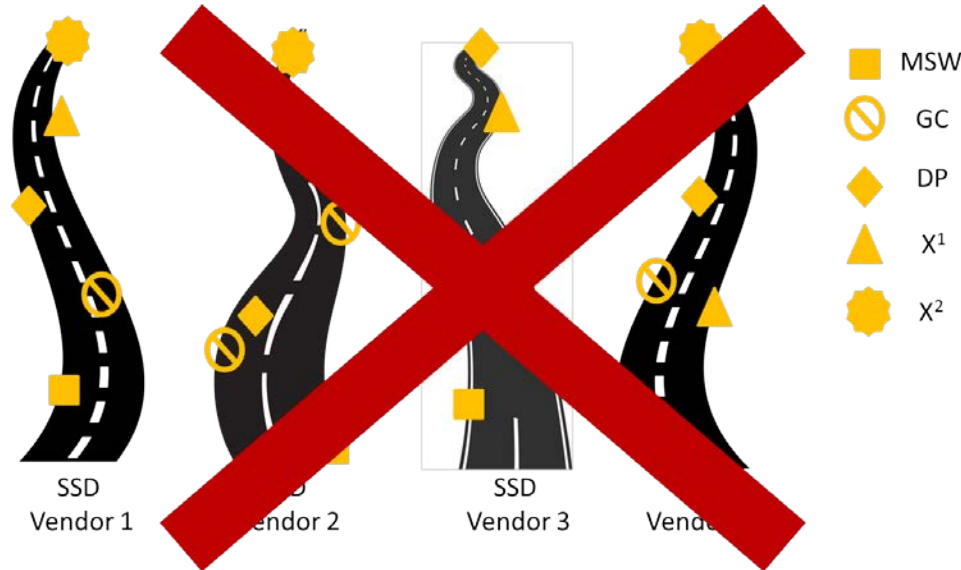
Lifecycle: Scheduling and Execution

System leverages workload knowledge and CFM visibility



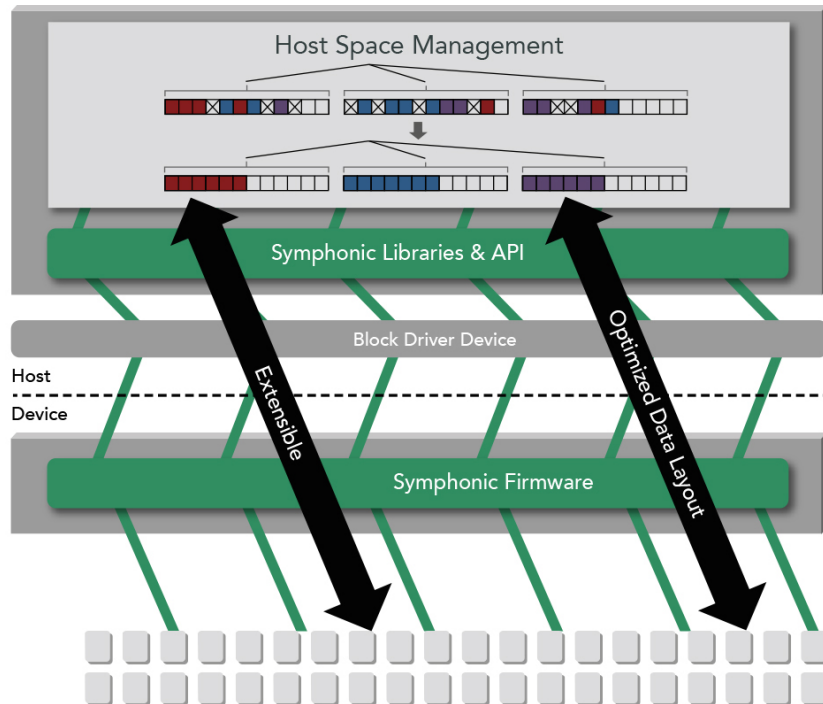
CFM Host Control

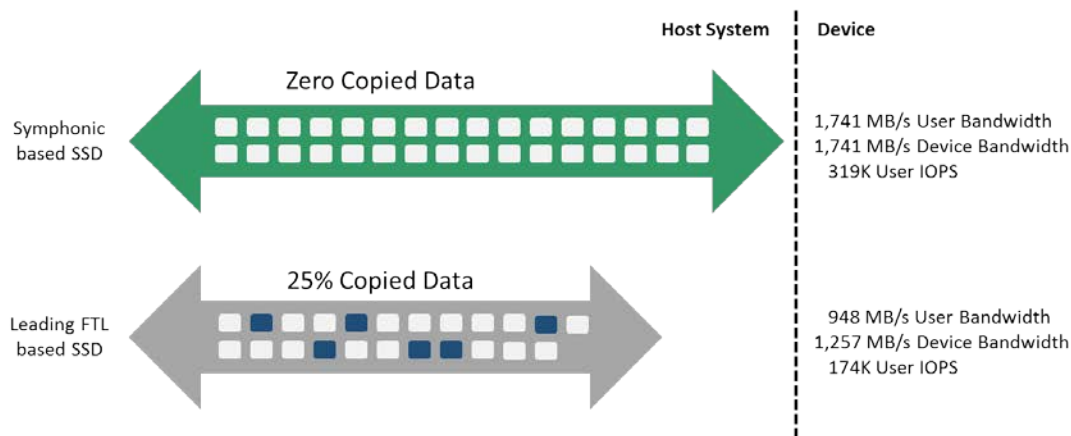
- System intelligence is left in the host and preserved to the media, so it's independent of the SSD



- Simple host contract from the outset – not a complex evolving interface

Extensibility & Parallelization



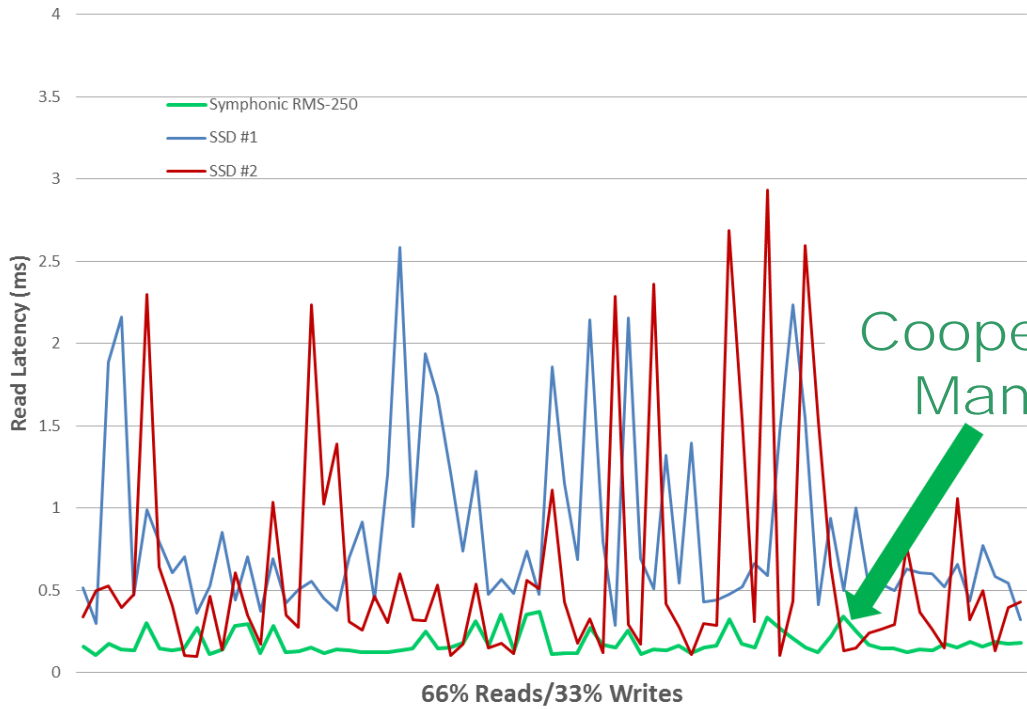


Workload: 66% random reads/33% sequential writes on random 8MB segments

Device Queue Depth: 128; Assumes 1.5 Host WA factor

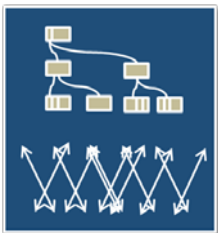
>80% improvement in IOPS and Bandwidth

Symphonic firmware turns the SSD into an offload engine, eliminating the copying that would normally occur between the host and SSD (copy overhead that would even occur with a HDD).

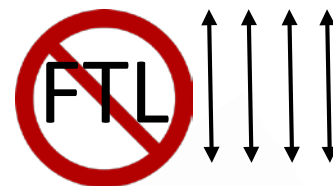


Cooperative Flash Management

Extremes

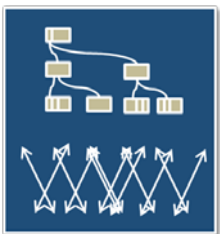


FTL SSD

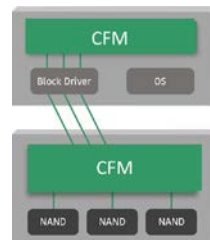


**True
SDF**

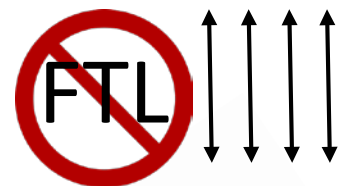
Goldilocks



FTL SSD



CFM SSD



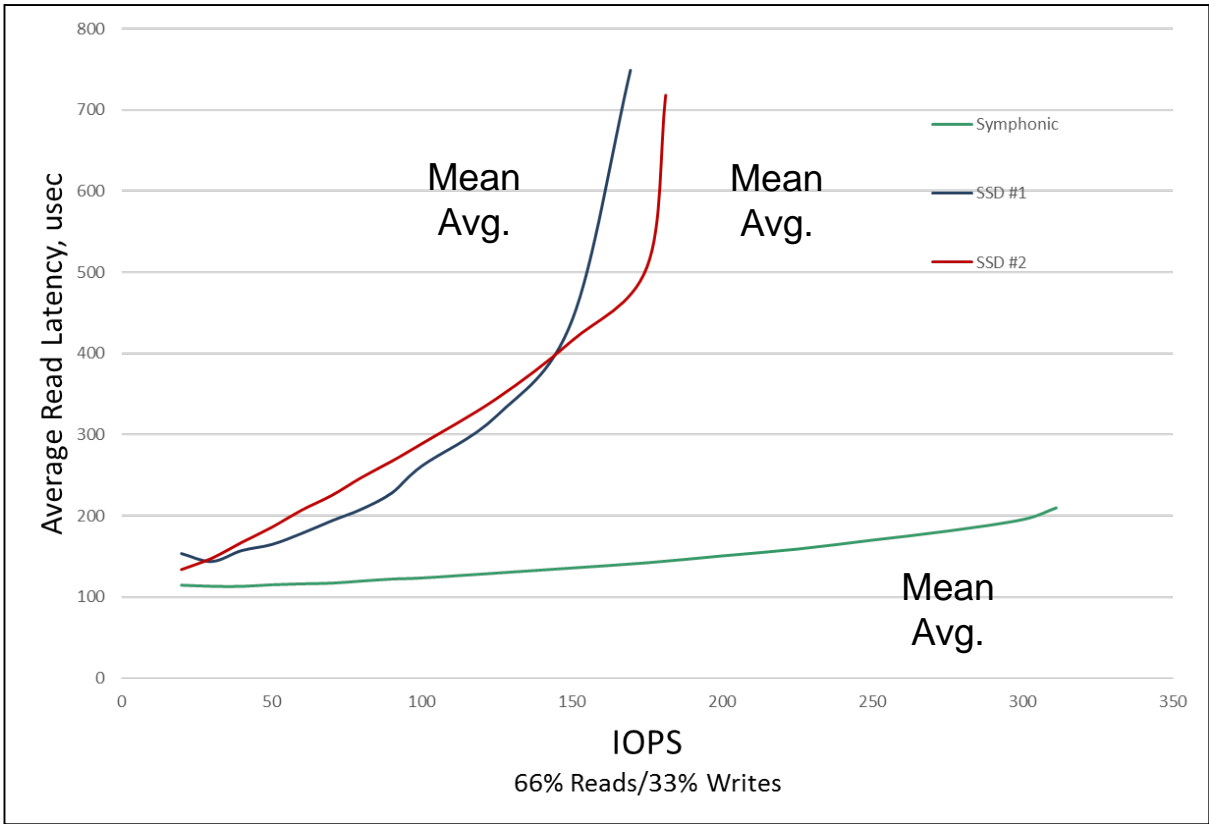
**True
SDF**

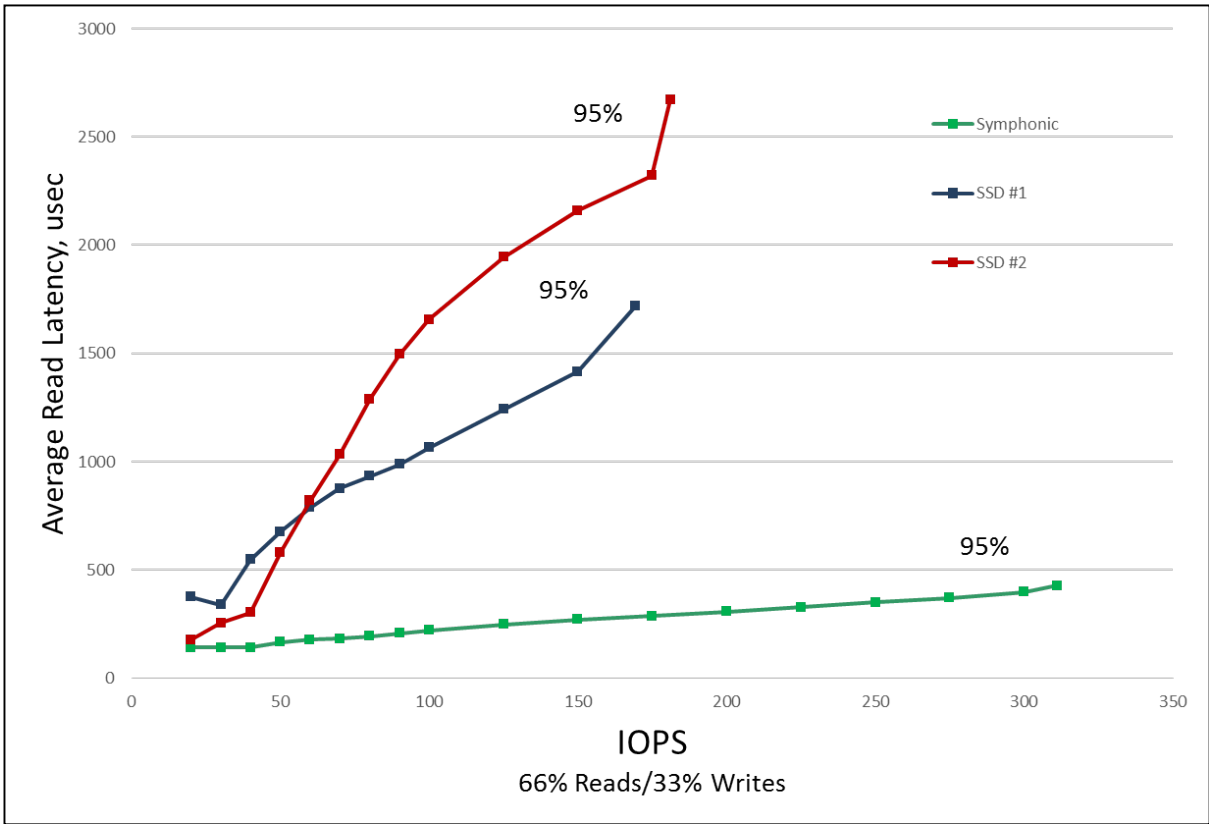
Flash is now the most important
Storage System media

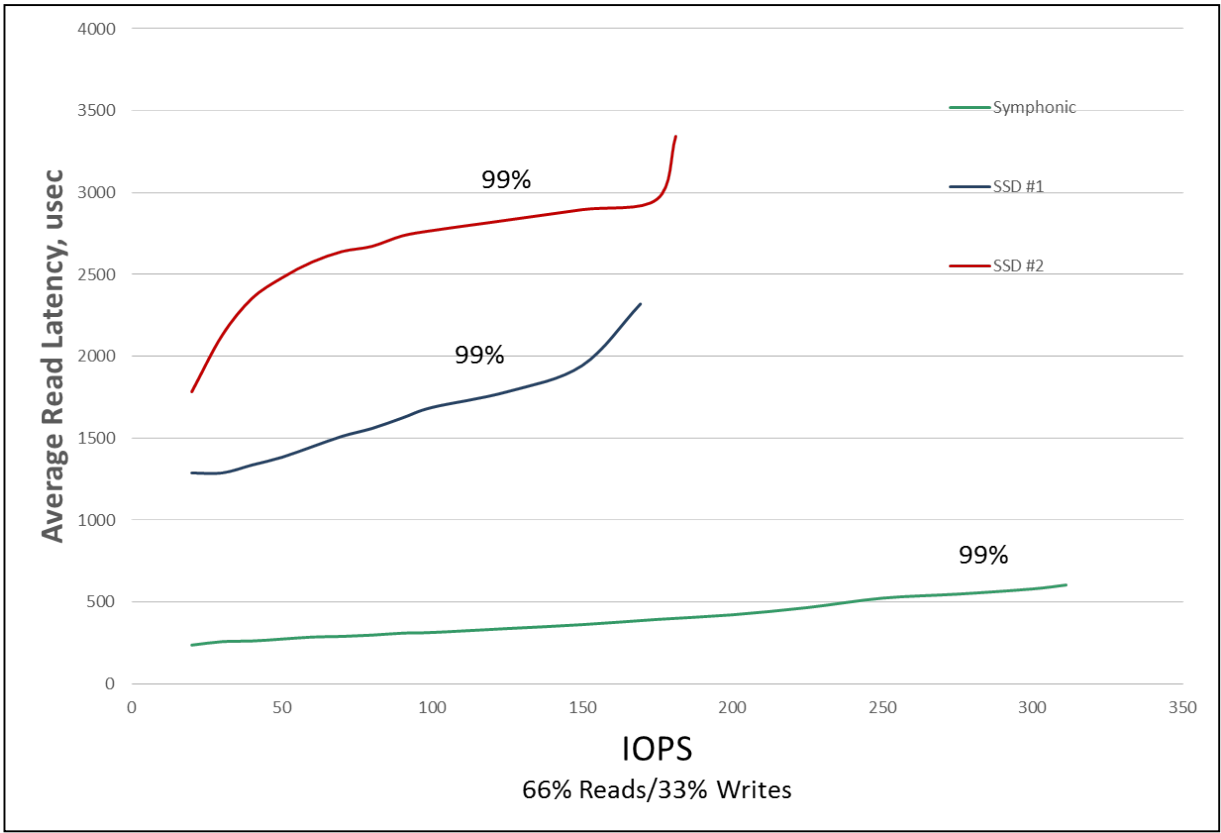
2015

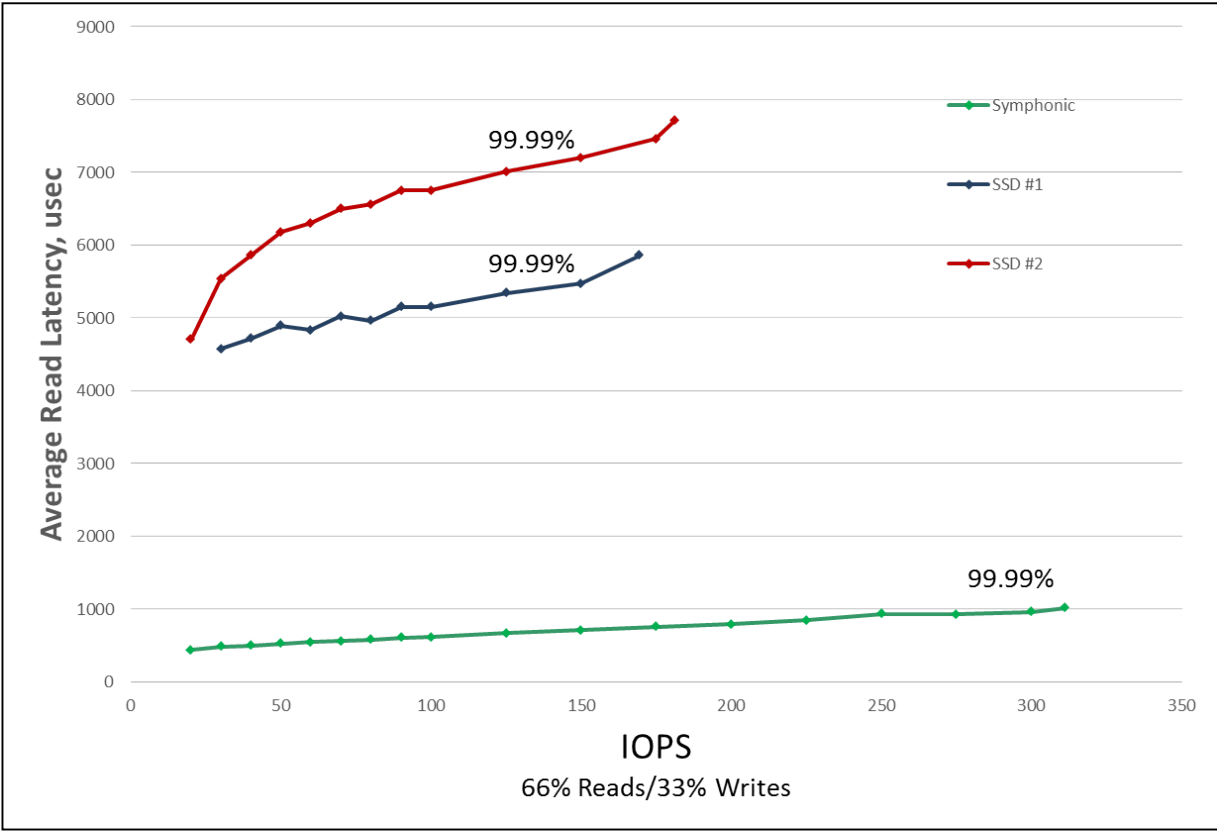


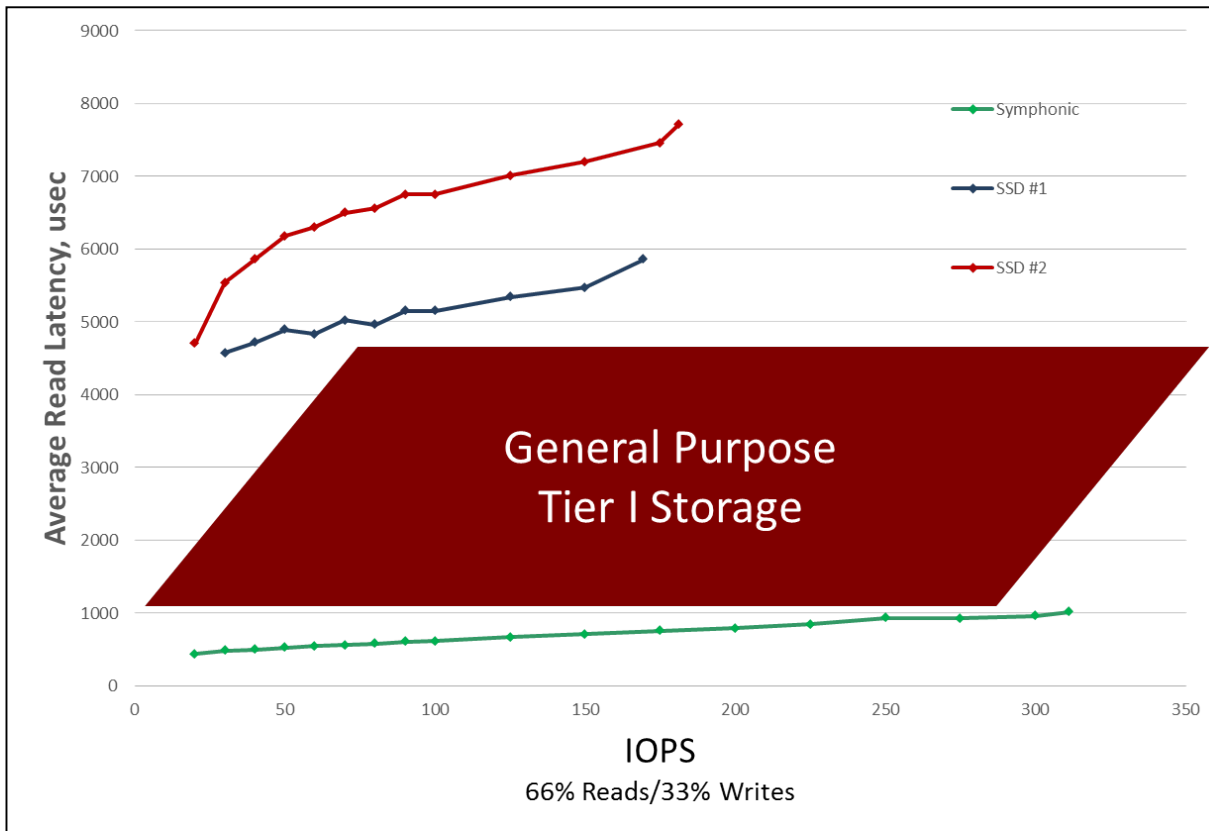
Where does Flash go
from here?











Data Center Primary Storage



WINTER IS COMING



HDD



Flash



DRAM

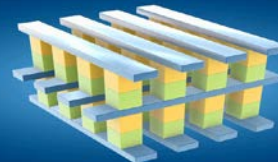
Data Center Primary Storage

WINTER IS COMING

HDD

Flash

3D XPOINT™



DRAM

Data Center Primary Storage

WORM

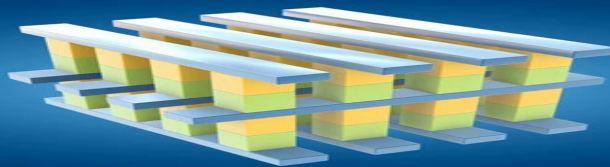
General
Purpose

RDBMS

HDD

FTL
Flash

3D XPOINT™



DRAM

Data Center Primary Storage

